Executive Summary

Axhandle Lake is currently a mesotrophic lake with good water clarity and water quality, but nutrients and algae have increased since 2000. The lake has excellent diversity of aquatic plant species and one of the highest quality plant communities in the state and region. The aquatic plant community in Axhandle Lake is characterized by a high intolerance to disturbance, an extreme closeness to an undisturbed condition and an assemblage of soft water species.

Najas gracillima was the dominant aquatic plant species, dominating all depth zones up to 15.5 feet; *Eleocharis acicularis* was the sub-dominant species. The 1.5-5-foot depth zone supports the most plant growth.

There has not been a significant change in the aquatic plant community between 1996 and 2004, but there have been some small changes. Some positive changes are:

1) An increase in the percentage of sites with emergent vegetation
2) An increase in the quality of the plant community as measured by the Floristic Quality Index and the Aquatic Macrophyte Community Index (Nichols 1998, 2000)
3) An increase in the number of plant species, Species Richness and species diversity.
4) An increase in all classifications of aquatic vegetation.

Some changes that have occurred may be of concern are:

1) An increase in the nutrient levels and algae growth
2) Increased density and occurrence of species that can become overabundant with increased nutrients.
3) An increase in the frequency and density of the dominant species
4) An increase in the number of commonly occurring species
5) An increase in the percent of vegetated sites
6) An increase in the total occurrence and density of plant growth

The watershed of Axhandle Lake is small; therefore, most nutrient inputs would likely come from the lakeshore properties.

A healthy aquatic plant community plays a vital role within the lake community. Plants provide improved water quality and valuable resources for fish and wildlife. Lakes with a healthy and diverse community of native aquatic plants are more resistant to invasions of non-native species and excessive growth of more tolerant species.

Management Recommendations

1) Protect the natural shoreline around the lake.
2) Restore natural buffers and emergent beds on shorelines that lack natural cover.
3) Continue participation in the volunteer water quality monitoring program.
4) Limit plant removal in Axhandle Lake, especially species valuable for habitat.
5) Designate Sensitive Areas in Axhandle Lake.
6) Maintain private septic systems in optimal condition.
7) Eliminate the use of lawn chemicals and fertilizers.

Changes in the Aquatic Plant Community of Axhandle Lake
Chippewa County, Wisconsin
1996-2004

I. INTRODUCTION

Studies of the aquatic plants (macrophytes) in Axhandle Lake were conducted during July 1996 and August 2000 and 2004 by the Lower Chippewa Basin staff of the Western Central Region - Department of Natural Resources (DNR).

A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake due to the important ecological role of aquatic vegetation and the ability of the vegetation to characterize the water quality (Dennison et al. 1993).

Ecological Role: All other life in the lake depends on the plant life (including algae) - the beginning of the food chain. Aquatic plants provide food and shelter for fish, wildlife, and the invertebrates that in turn provide food for other organisms. Plants improve water quality, protect shorelines and lake bottoms and add to the aesthetic quality of the lake.

Characterize Water Quality: Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et. al. 1993).

The present study will provide information that is important for effective management of the lake including fish habitat improvement, protection of sensitive wildlife areas, aquatic plant management, and water resource regulations. The data that it provides will be compared to past and future plant inventories and offer insight into any changes occurring in the lake.

Background

Axhandle Lake is an 84-acre natural seepage lake in northwest Chippewa County, Wisconsin. Axhandle Lake has a maximum depth of 73 feet and a mean depth of 19 feet. The ratio of drainage area to lake surface is 3.2:1 (Pippenger 1994). This indicates a relatively small watershed that (Figure 1) would not significantly impact the water quality of the lake through run-off. There are intermittent inflows from Dark Lake and Woodpecker Lake via Ten Mile Creek. Water flows out to Ten-Mile Creek.

II.METHODS

Field Methods

The same study design and transects were used in the 1996, 2000 and 2004 studies. It was based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of the transect lines (Appendix XI). The shoreline was divided into 30 equal segments and within each segment, a transect was randomly placed, using a random numbers table.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, 5-10ft and 10-20ft) along each transect. Using a long-handled steel-thatching rake, four rake samples were taken at each sampling site. The four samples were taken from each quarter of a 6-foot square quadrat. The aquatic plant species that were present on each rake sample were recorded. Each species was given a density rating (0-5) based on the number of rake samples on which it was present at each sampling site.

A rating of 1 indicates the species was present on 1 rake sample
A rating of 2 indicates the species was present on 2 rake samples
A rating of 3 indicates the species was present on 3 rake samples
A rating of 4 indicates the species was present on all 4 rake samples
A rating of 5 indicates the species was abundantly present on all 4 rake samples at that site.

The actual depth and sediment type at each sampling site was recorded.

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on either side of the transect intercept with the shore and 30 feet back from the shore, was evaluated. The percentage of each cover type within this 100' x 30' rectangle was estimated.

Visual inspection and periodic samples were taken between transect lines in order to record the presence of any species that did not occur at the sampling sites. Specimens of all plant species present were collected and saved in a cooler for later preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

Data Analysis

The data for each year was analyzed separately and compared. The percent frequency of occurrence of each species was calculated (number of sampling sites at which it occurred / total number of sampling sites) (Appendix I-III). Relative frequency was calculated for each species (number of sampling sites at which it occurred / sum of all species occurrences (Appendix I-III). The mean density was calculated for each species (sum of a species' density ratings / number of sampling sites) (Appendix IV-VI). Relative density was calculated (sum of a species' density ratings / sum of all plant densities) (Appendix IV-VI). A "mean density where present" was calculated for each species (sum of a species' density ratings / number of sampling sites at which the species occurred) (Appendix IV-VI). The relative frequency and relative density were summed to obtain a dominance value (Appendix VII-IX).

Simpson's Diversity Index was calculated (Appendix I-III). Each sampling year was compared by a Coefficient of Community Similarity (Table 9).

An Aquatic Macrophyte Community Index (AMCI), developed for Wisconsin lakes, was applied to Axhandle Lake (Table 11). Data in six categories that characterize the aquatic plant community is converted to values 0 - 10 and combined as outlined by Nichols et. al. (2000).

Coefficients of Conservatism and Floristic Quality Index were used to evaluate the closeness of the aquatic plant community to an undisturbed condition (Nichols 1998) (Table 12). A Coefficient of Conservatism is an assigned value, 0-10, the probability that a species will occur in a relatively undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients of conservatism for all species found in a lake; the Floristic quality Index is calculated from the Average Coefficients.

III. RESULTS

PHYSICAL DATA

Many physical parameters impact the aquatic plant community. Water quality (nutrients, algae and clarity) influence the plant community as the plant community can in turn modify these parameters. Lake morphology, sediment composition and shoreline land use can impact the plant community.

WATER QUALITY

The trophic state of a lake is an indicator of water quality.
Eutrophic lakes are high in nutrients and support a large biomass.
Oligotrophic lakes are low in nutrients and support limited plant growth and smaller populations of fish.
Mesotrophic lakes have intermediate levels of nutrients and biomass.

Phosphorus (nutrient), chlorophyll (algae), and Secchi (water clarity) data are collected and combined to determine the trophic state.

Phosphorus is a limiting nutrient in many Wisconsin lakes; therefore, increases of phosphorus in a lake can feed algal blooms and sometimes promote excessive plant growth. Phosphorus data collected from Axhandle Lake in 1977, 1994 and 2000 remained within the oligotrophic range (Figure 1; Table 1). However, phosphorus has been increasing and reached the mesotrophic range in 2001-2004, which would result in more plant growth and more frequent algae blooms.

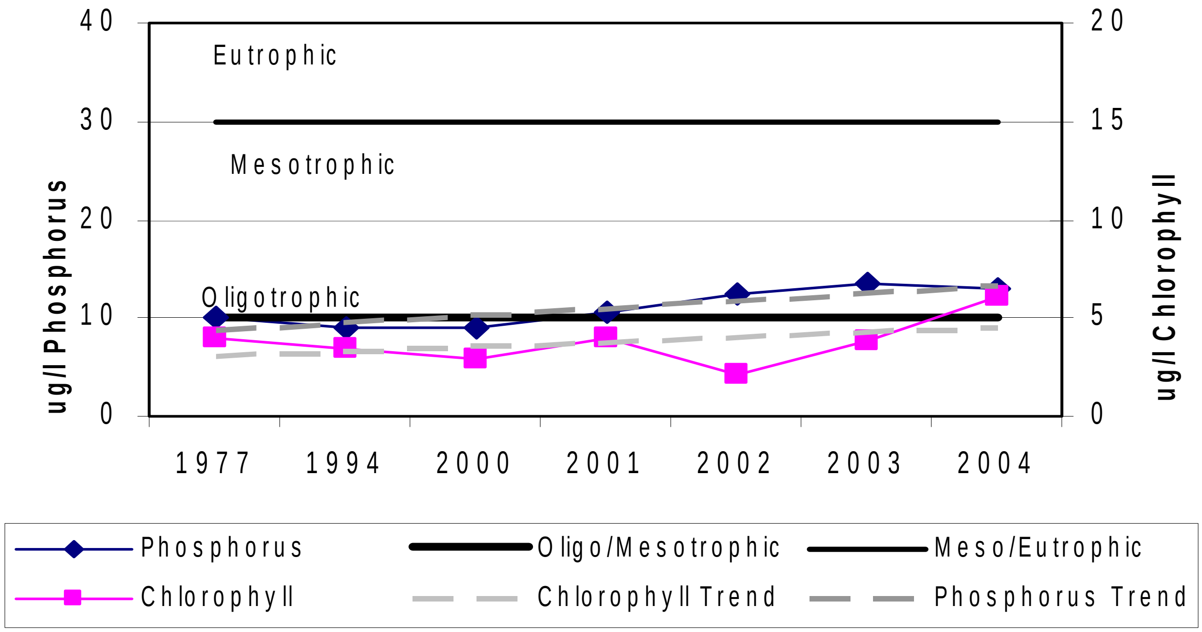

Figure 1. Phosphorus and chlorophyll in Axhandle Lake, 1977-2004.

Measuring the amount of chlorophyll in a lake gives an indication of algae concentration. Algae are natural and essential in lakes, but high algal levels contribute to higher turbidity, thus reducing the light availability for plant growth.

The chlorophyll concentrations in Axhandle Lake were also in the oligotrophic range, increasing into the mesotrophic range in 2004 (Figure 2) (Table 1). This verifies that increased nutrients are resulting in increased algae.

Table 1. Axhandle Lake Trophic Status

	Quality Index	Phosphorus ug/l	Chlorophyll ug/l	Secchi Disc foot
Oligotrophic	Excellent	<1	<1	> 19
	Very Good	1-10	1-5	**8-19**
Mesotrophic	Good	**10-30**	**5-10**	6-8
	Fair	30-50	10-15	5-6
Eutrophic	Poor	50-150	15-30	3-4
Hypereutrophic	Very Poor	>150	>30	>3
Axhandle Lake – 2004 Summer Mean	Good	13	6.11	10.8

After Lillie & Mason (1983) & Shaw et. al. (1993)

During the growing season, phosphorus is fairly stable until an increase in September. Algae concentrations gradually increases through August as water temperatures increase and become favorable to increased algae growth (Figure 2).

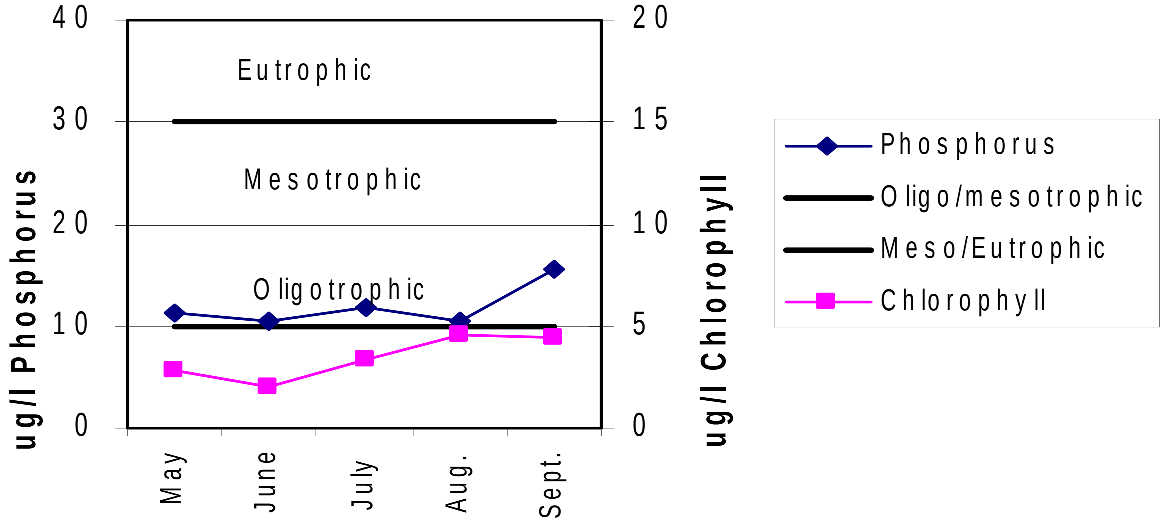

Figure 2. Changes in phosphorus and chlorophyll during the growing season.

Filamentous algae was not found at the sample sites in Axhandle Lake in 1996, but occurred at 11% of the sampling sites (one-third of the sample sites in the shallow zone) in 2000 and only 1% of the sites in 2004 (Table 2).

Table 2. Filamentous Algae in Axhandle Lake, 1996-2004

Depth Zone	1996	2000	2004
0-1.5 ft.	0%	33%	0%
1.5-5 ft.	0%	7%	3%
5-10 ft.	0%	3%	0%
10-20 ft.	0%	4%	0%
Total	0%	11%	1%

Water clarity is a critical factor for plants. When plants receive less than 1 - 2% of the surface illumination, they can not survive. Aquatic plant species vary in their tolerance to low water clarity, so that changes in water clarity could cause shifts in an aquatic plant community. Water clarity is reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color the water. Water clarity can be measured with a Secchi disc that shows the combined effect of turbidity and color.

The 1994 and 2000-2004 water clarity in Axhandle Lake has varied in different years but has remained good, in the oligotrophic range (Figure 3).

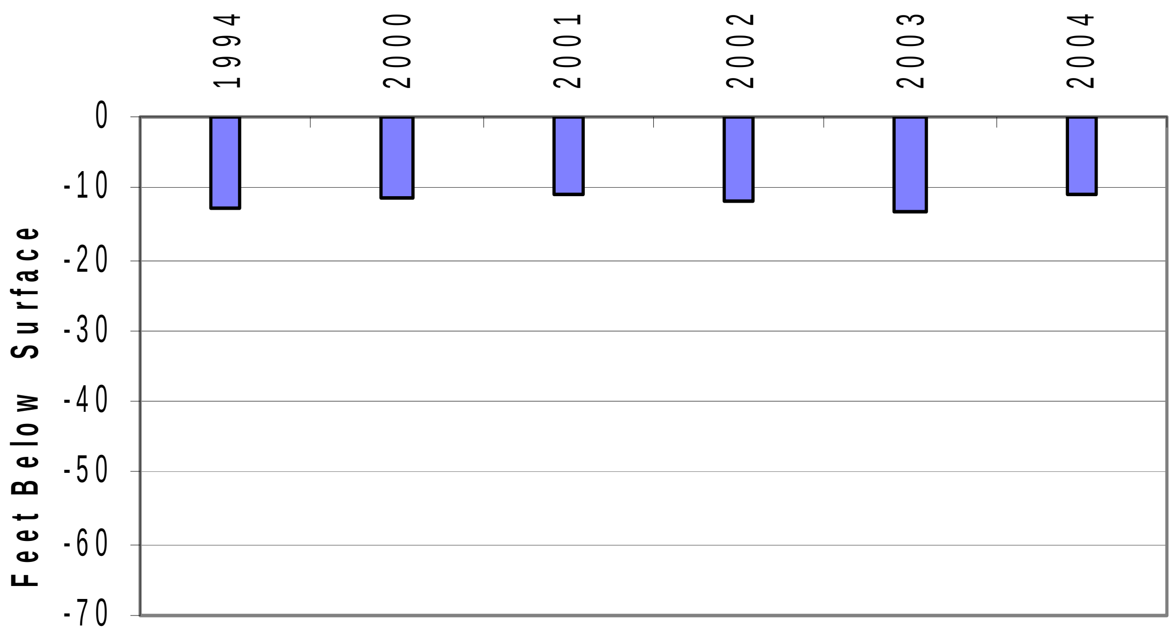

Figure 3. Secchi Disc water clarity in Axhandle Lake, 1994-2004.

The combination of phosphorus (nutrient), chlorophyll (algae) and water clarity values indicates the trophic state of a lake. These values for Axhandle Lake indicate that it has been an oligotrophic lake with very good water quality that is changing to a mesotrophic lake with good water quality. This change would favor higher levels of plant growth, lower water clarity and more frequent algae blooms.

Alkalinity

The mean alkalinity of Axhandle Lake is 10.3 mg CaCo3/l. Water with less than 60mg CaCo3/l is considered soft water. Soft water lakes tend to have less plant growth.

LAKE MORPHOMETRY - The morphometry of a lake is a factor in analyzing the distribution of aquatic plants. Duarte and Kalff (1986) found that the slope of the littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support more plant growth than steep slopes (Engel 1985).

Axhandle Lake has an irregularly shaped basin and an extremely irregular shoreline with a moderately sloped littoral zone. Areas with gradually-sloped littoral zone would favor plant growth and those with steeply-sloped zones would discourage plant growth.

SEDIMENT COMPOSITION – Silt/sand mixture was the dominant sediment in Axhandle Lake in 2004 (Table 3), especially at depths greater than 1.5ft. Sand was common in Axhandle Lake, at depths greater than 1.5ft. A sand/rock mixture was dominant in the shallowest depth zone, 0-1.5ft and declined rapidly with increasing depth (Table 3).

Table 3. Sediment Occurrence in Axhandle Lake, 2004

		0-1.5ft Depth	1.5-5ft Depth	5-10ft Depth	10-20ft Depth	Overall
Soft Sediments	**Silt**			23%	34%	14%
	Peat	3%	3%			2%
Mixed Sediments	**Silt/Sand**		40%	40%	41%	30%
	Sand/Peat	13%	3%	3%	3%	6%
	Silt/Rock			10%		2%
	Sand/Silt Rock/ Peat	3%	6%			2%
Hard Sediments	**Sand**	13%	33%	20%	21%	22%
	Sand/Rock	37%	10%	3%		13%
	Sand/Gravel	30%	3%			1%

SEDIMENT INFLUENCE

Some plants depend on the substrate in which they are rooted for nutrients. The richness or sterility of the sediment can influence which plant species can survive and how abundantly they grow.

Silt/sand was the dominant sediment and sand sediments were common in Axhandle Lake in 2004 (Table 4).

High-density sediments such as sand and rock are lower in nutrients and support less plant growth. Silt sediments are most favorable for plant growth because of their intermediate density. Nutrient availability is greatest in sediments of intermediate density, such as silt (Barko and Smart 1986).

Sediment does not appear to be a limiting factor in Axhandle Lake; all sediment types in Axhandle Lake had high levels of vegetation growth (Table 4).

Table 4. Sediment Influence

		2004	
		% Occur	**% Vegetated**
Soft Sediments	**Silt**	14%	98%
	Peat	2%	100%
	Muck		
Mixed Sediments	**Silt/Sand**	30%	92%
	Sand/silt/Rock/Peat	8%	100%
	Silt/Rock	2%	100%
Hard Sediments	**Sand**	22%	100%
	Sand/Rock/Gravel	14%	93%
	Rock/Gravel		

SHORELINE LAND USE - Land use practices strongly impact the aquatic plant community and therefore, the aquatic habitat. Practices on shore can directly impact the plant community through increased sedimentation from erosion, increased nutrient levels from fertilizer run-off and soil erosion and increased toxics from farmland and urban run-off.

Wooded cover had the highest occurrence and mean coverage at the shoreline transects in Axhandle Lake. Native herbaceous cover and shrub growth were also commonly occurring (Table 5).

However, disturbed shoreline was also commonly occurring (Table 5).

1) Cultivated lawn, which was found at nearly one-third of the sample sites, can result in increased rates of run-off and increased input of fertilizers and pesticides.
2) Hard structures occurred at nearly half the sites and rip-rap was commonly occurring. Run off rates increase over hard structures and surfaces. Rip-rap does not filter run-off as well or provide quality habitat as does biological methods of shore stabilization.

Table 5. Shoreline Land Use, Axhandle Lake 2004

Cover Type		**Frequency of Occurrences at Transects**	**Mean % Coverage**
Natural Shoreline	Wooded	90%	65%
	Native Herbaceous	50%	9%
	Shrub	33%	4%
	Rock	7%	1%
Total		90%	79%
Disturbed Shoreline	Cultivated Lawn	30%	11%
	Hard Structure	47%	7%
	Rip-rap	20%	2%
	Bare Sand	17%	1%
Total		53%	21%

Natural shoreline occurred at 90% of the sample sites, but disturbed shoreline occurred at 53% of the sample sites. If the sample sites are representative of the rest of the lake, natural shoreline protects 79% of the shoreline and disturbed shoreline impacts 21% of the shoreline within 30 feet of the shore.

AQUATIC PLANT DATA

SPECIES PRESENT

Of the 40 species that have been recorded in Axhandle Lake, 14 were emergent species, 4 were floating-leaf species, and 22 were submergent species (Table 6).

No non-native species were found.

No endangered or threatened species were found. One Species of Special Concern was found: *Myriophyllum farwellii.* Special Concern Species are species with which there is a concern about their lack of abundance or distribution. The purpose of this designation is to focus attention on these species before they become threatened or endangered.

Table 6. Axhandle Lake Aquatic Plant Species, 1996-2004

Scientific Name	Common Name	I. D. Code
Emergent Species		
1) *Asclepias incarnata* L.	swamp milkweed	ascin
2) *Calamagrostis canadensis* (Michx.) P.Beauv.	bluejoint grass	calca
3) *Calla palustris* L.	water arum	calpa
4) *Carex stricta* Lam.	sedge	carst
5) *Chamaedaphne calyculata* (L.) Moench.	leatherleaf	chaca
6) *Cladium mariscoides* (Muhl.) Torr.	twig rush	clama
7) *Dulichium arundinaceum* (L.) Britton	three-way sedge	dular
8) *Eleocharis smallii* Britt.	creeping spikerush	elesm
9) *Juncus effusus* L.	soft rush	junef
10) *Osmunda regalis* L.	royal fern	osmre
11) *Pontederia cordata* L.	pickerelweed	ponco
12) *Sagittaria graminea* Michx.	grass-leaved arrowhead	saggr
13) *Scirpus validus* Vahl.	softstem bulrush	sciva
14) *Triadenum fraseri* (Spach) Gleason	marsh St. John's-wort	trifr
Floating-leaf Species		
15) *Brasenia schreberi* J. F. Gmelin	watershield	brasc
16) *Nuphar variegata* Durand.	bull-head pond lily	nupva
17) *Nymphaea odorata* Aiton.	white water lily	nymod
18) *Sparganium fluctuans* (Morong) Robinson	floating-leaf burreed	spafl
Submergent Species		
19) *Elatine minima* (Nutt.) Fischer & Meyer	waterwort	elami
20) *Eleocharis acicularis* (L.) Roemer & Schultes	needle spikerush	eleac
21) *Eriocaulon aquaticum* (Hill) Druce.	pipewort	eriaq
22) *Fontinalis* sp.	watermoss	fonsp
23) *Isoetes echinospora* Durieu.	spiny-spored quillwort	isoec
24) *Juncus pelocarpus* E. Meyer.	brown-fruited rush	junpe
25) *Myriophyllum farwellii* Morong.	Farwell's water-milfoil	myrfa
26) *Myriophyllum tenellum* Bigelow.	dwarf water milfoil	myrte
27) *Najas flexilis* (Willd) Rostkov & Schmidt	northern water-nymph	najfl
28) *Najas gracillima* (A. Braun) Magnus	slender water-nymph	najgr
29) *Nitella* sp.	nitella	nitsp
30) *Potamogeton epihydrus* Raf.	ribbon-leaf pondweed	potep
31) *Potamogeton foliosus* Raf.	leafy pondweed	potfo
32) *Potamogeton gramineus* L.	variable-leaf pondweed	potgr
33) *Potamogeton natans* L.	floating-leaf pondweed	potna
34) *Potamogeton oakesianus* Robbins.	Oakes' pondweed	potoa
35) *Potamogeton pusillus* L.	slender pondweed	potpu
36) *Potamogeton spirillus* Tuckerman.	n. snail-seed pondweed	potsp
37) *Ranunculus flammula* L.	creeping spearwort	ranre
38) *Sagitarria* sp.	rosettes of arrowhead	sagsp
39) *Utricularia gibba* L.	small bladderwort	utrgi
40) *Vallisneria americana* L.	water celery	valam

FREQUENCY OF OCCURRENCE

The species with the highest frequency of occurrence all three study years was *Najas gracillima* (Table 7). Other species that were commonly occurring 1996-2004 were *Eleocharis acicularis* and *Isoetes echinospora* (Table 7). *Potamogeton spirillus* was common 2000-2004; *Sagittaria* spp., *Nymphaea odorata* and *Brasenia schreberi* were common in 2004. The frequency of all of the common species increased during 1996-2004.

Table 7. Frequencies of Prevalent Aquatic Plant Species in Axhandle Lake.

Species	1996	2000	2004
Najas gracillima	63%	54%	66%
Eleocharis acicularis	30%	33%	36%
Isoetes echinospora	23%	24%	33%
Potamogeton spirillus	3%	30%	30%
Sagittaria spp.	11%	6%	29%
Nymphaea odorata	17%	15%	25%
Brasenia schreberi	5%	14%	21%

DENSITY

In addition to occurring at the highest frequency, *Najas gracillima* was also the species with the highest mean density during 1996-2004 (Table 8). The mean density of all the prevalent aquatic plant species increased from 1996 to 2004 (Table 8).

Table 8. Mean Densities of Prevalent Aquatic Plant Species in Axhandle Lake, 1996-2004.

Species	1996	2000	2004
Najas gracillima	1.50	1.32	1.87
Eleocharis acicularis	0.62	0.64	0.73
Isoetes echinospora	0.35	0.42	0.47

The “mean density where present” indicates the density or aggregation of a specie’s growth forms in Axhandle Lake (Appendix IV-VI). Even though a species may not occur frequently within a lake, where it does occur, it grows densely.

In 1996, *Cladium mariscoides, Najas flexilis, Nitella* sp. and *Sagittaria graminea* had above average “mean densities where present” (4.0, 4.0, 3.14 and 3.36) (Appendix IV).

In 2000, *Potamogeton gramineus* had an above average “mean density where present” (4.0) (Appendix V).

In 2004, *Calla palustris* and *Nitella* spp. had an above average “mean density where present” (3.0) (Appendix VI). All of theses species had low occurrence in Axhandle Lake, except *Sagittaria graminea*. So, although these species exhibited an aggregated or dense growth form, they occurred in only a few locations in Axhandle Lake.

DOMINANCE

Combining the relative frequency and relative density of a species into a dominance value, illustrates how dominant a species is within the plant community. Based on the dominance value, *Najas gracillima* was the dominant species in Axhandle Lake in all studies (Figure 4); maintaining stable levels during 1996-2004. *N. gracillima* is limited to soft water lakes such as Axhandle Lake.

Eleocharis acicularis was the sub-dominant in all studies, also maintaining a stable level in the Axhandle Lake aquatic plant community (Figure 4).

The dominance of *Nymphaea odorata* and *Sagittaria graminea* declined slightly from 1996 to 2000, but *Sagittaria graminea* rebounded in 2004. The dominance of *Potamogeton spirillus* increased from 1996-2000 (Figure 4).

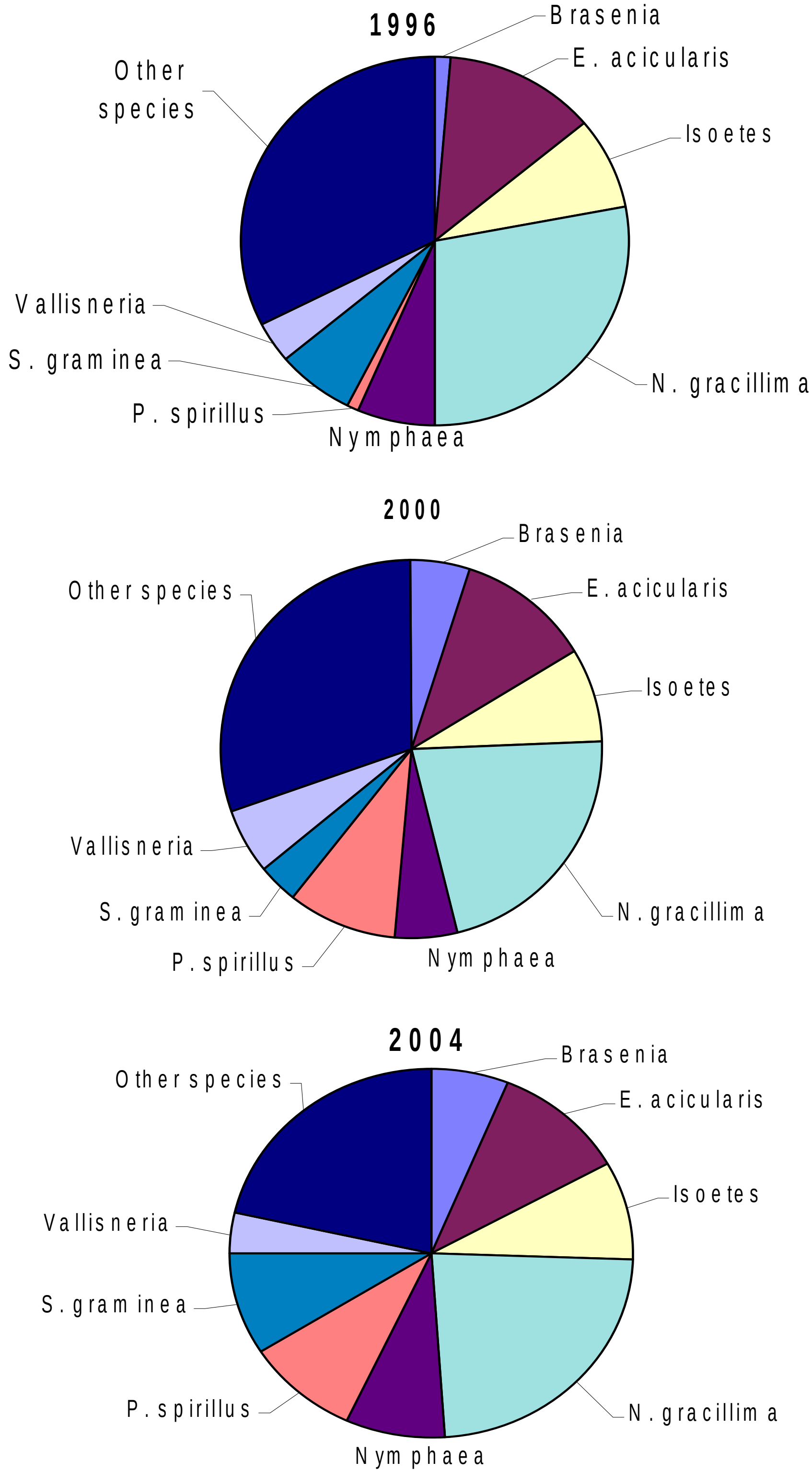

Figure 4. Dominance of the most prevalent aquatic plants within the aquatic plant community of Axhandle Lake1996-2004.

DISTRIBUTION

Rooted aquatic plants were found growing at 92% of all sampling sites in 1996 and at 95% of sampling sites in 2000 and 2004. *Nitella* sp. has been found at the greatest depth (30 feet). However, *Nitella* sp. is a macrophytic algae, not a rooted aquatic plant. The greatest rooting depth was at 15.5 feet. *Isoetes echinospora, Najas gracillima* and *Potamogeton pusillus* occurred at the maximum rooting depth.

Secchi disc water clarity data can be used to calculate the predicted maximum rooting depth (Dunst 1982). The predicted maximum rooting depth in 2004, was calculated to be 15.9 ft, close to the actual maximum rooting depth of 15.5 feet.

All depth zones, in all years years, had a high percentage of vegetated sites (Figure 5). The depth zone with the highest percent of vegetated sites in 1996 was the 5-10ft depth zone; in 2000, the 10-20ft depth zone; in 2004, the 1.5-10ft depth zone (Figure 5).

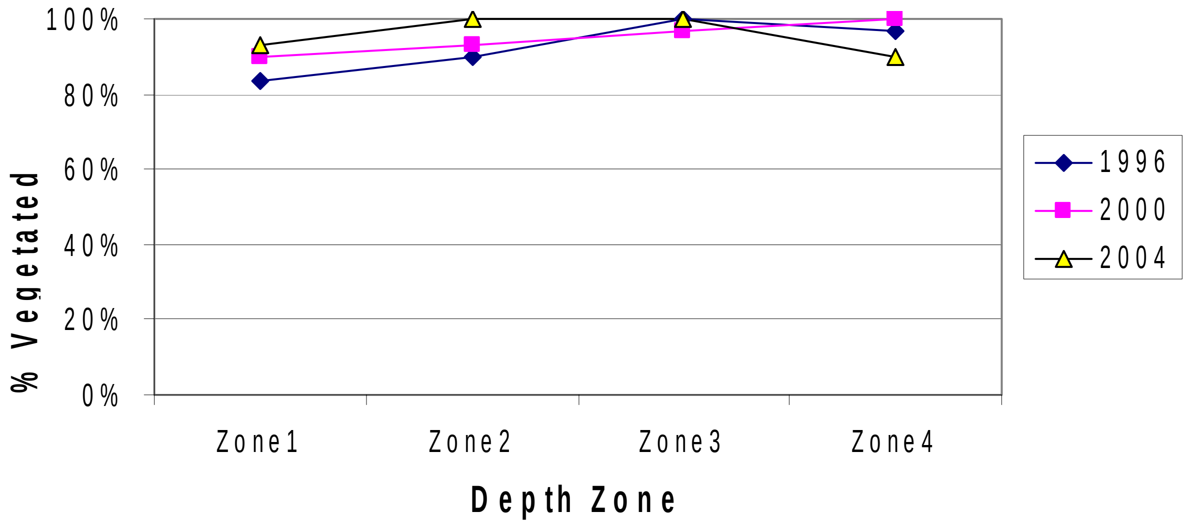

Figure 5. Percent of vegetated in Axhandle Lake, by depth zone, 1996-2004.

The Species Richness (mean number of species at each sampling site) has steadily increased from 1996 to 2004 (Figure 6). The greatest Species Richness has been in the 1.5-5ft depth zone.

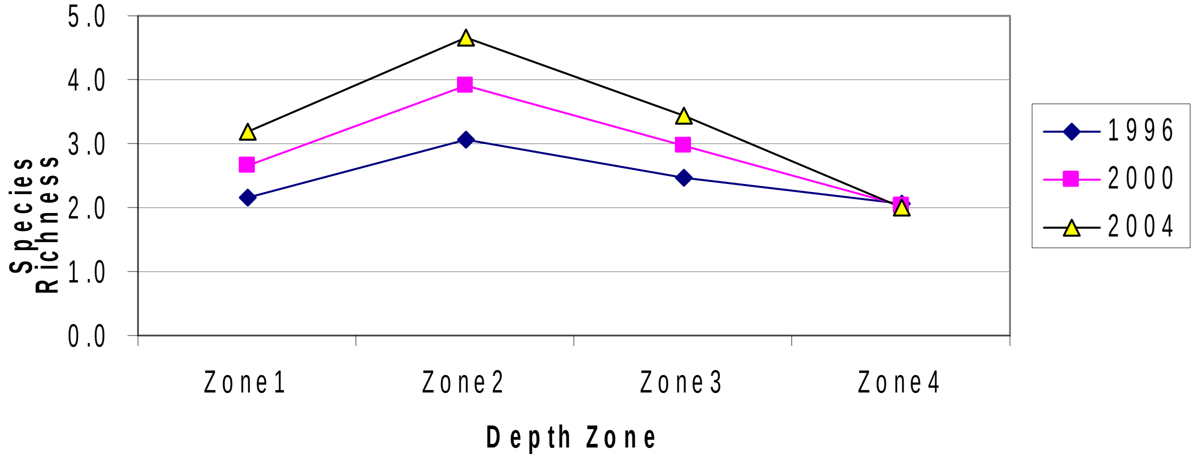

Figure 6. Species Richness (mean number of species per site) by depth zone.

The total occurrence of plant growth has also steadily increased from 1996 to 2004. The 1.5-5ft depth zone had the highest total occurrence of aquatic plants (Figure 7).

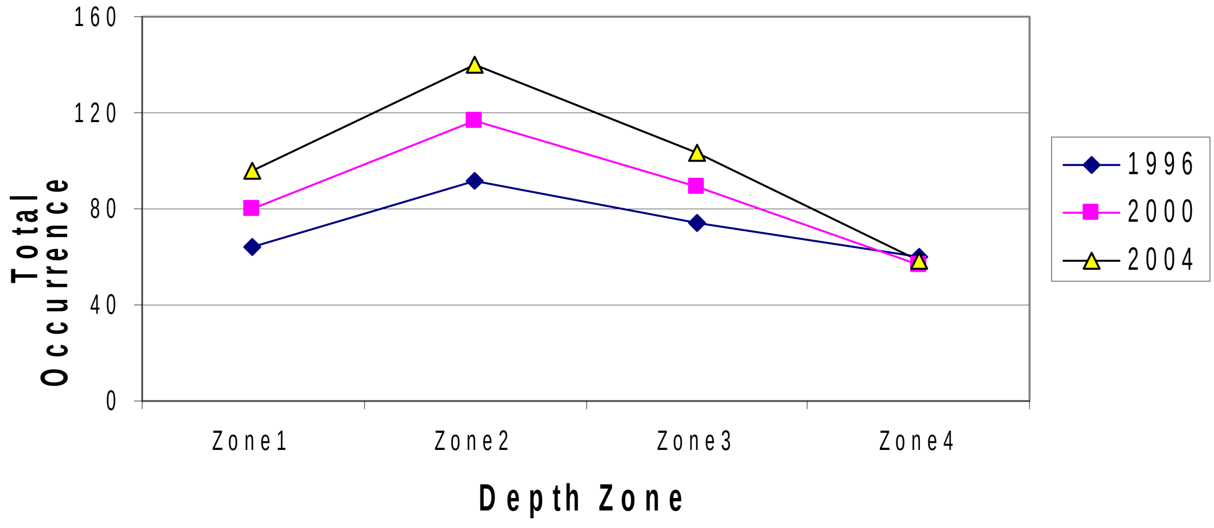

Figure 7. Total occurrence of aquatic plants by depth zone, Axhandle Lake.

The total density of plant growth increased steadily between 1996 and 2004 (Figure 8). The total density of plant growth has been highest in the 1.5-5ft depth zone, (Figure 8).

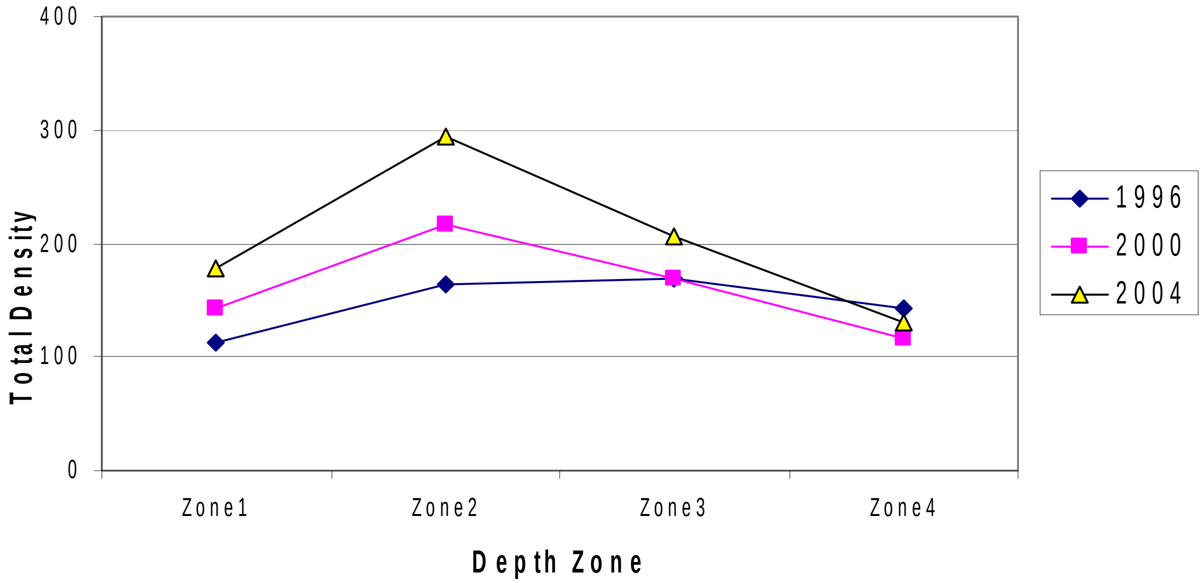

Figure 8. Total density of aquatic plants by depth zone, Axhandle Lake.

The most common species in Axhandle Lake were found throughout the lake in all years. However, *Nymphaea odorata* appeared to be absent from the eastern shore of the main part of the lake in all years. And *Brasenia schreberi* and *Sagittaria* sp. rosettes appeared to be absent from much of the west shore of the main lake in 2004. These areas are where much of the "traditional cottage development" is located.

Najas gracillima, the dominant species, dominating all depth zones in 1996 and 2004, although *Eleocharis acicularis* had a higher mean density in the 1.5-5ft depth zone (Figure 9, 10, 12). *N. gracillima* occurs at its highest density in the 10-20ft depth zone (Figure 10).

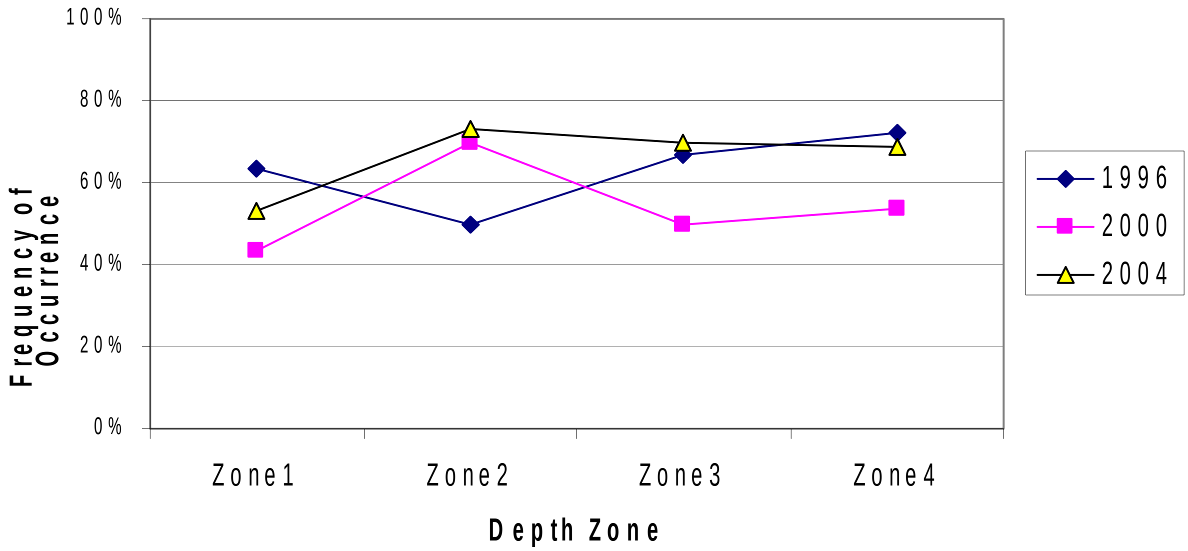

Figure 9. Frequency of *Najas gracillima*, by depth zone, 1996-2004.

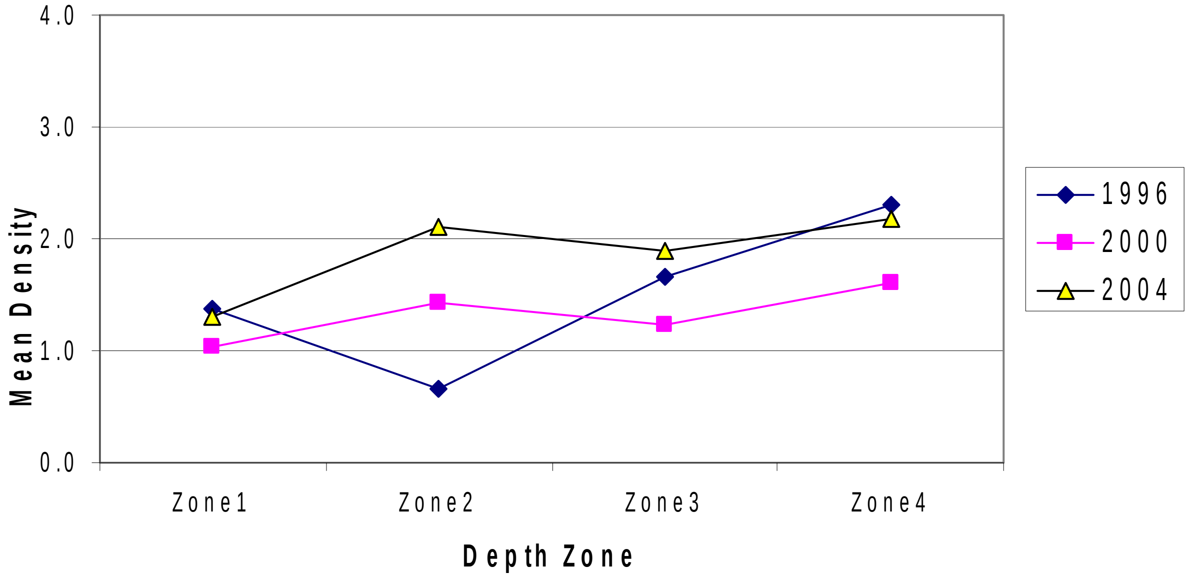

Figure 10. Mean density of *Najas gracillima*, by depth zone, 1996-2004.

Eleocharis acicularis was the most densely occurring species in the 1.5-5 foot depth zone in 1996 (Figure 12). *E. acicularis* occurred at its highest frequency and density in the 5-10ft depth zone (Figure 11, 12).

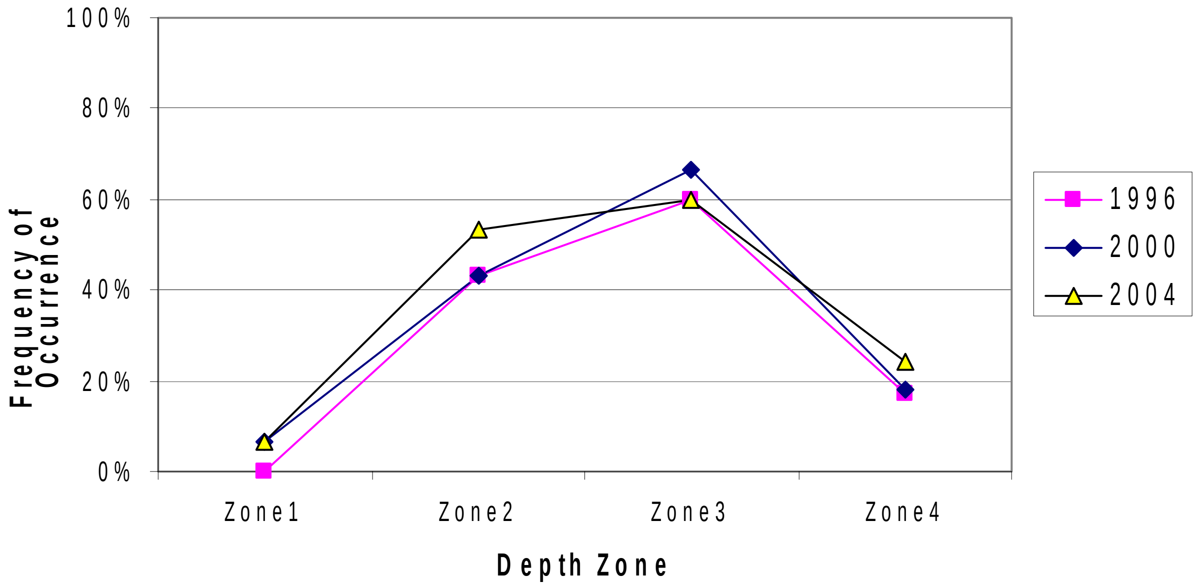

Figure 11. Frequency of *Eleocharis acicularis,* 1996-2004, by depth zone.

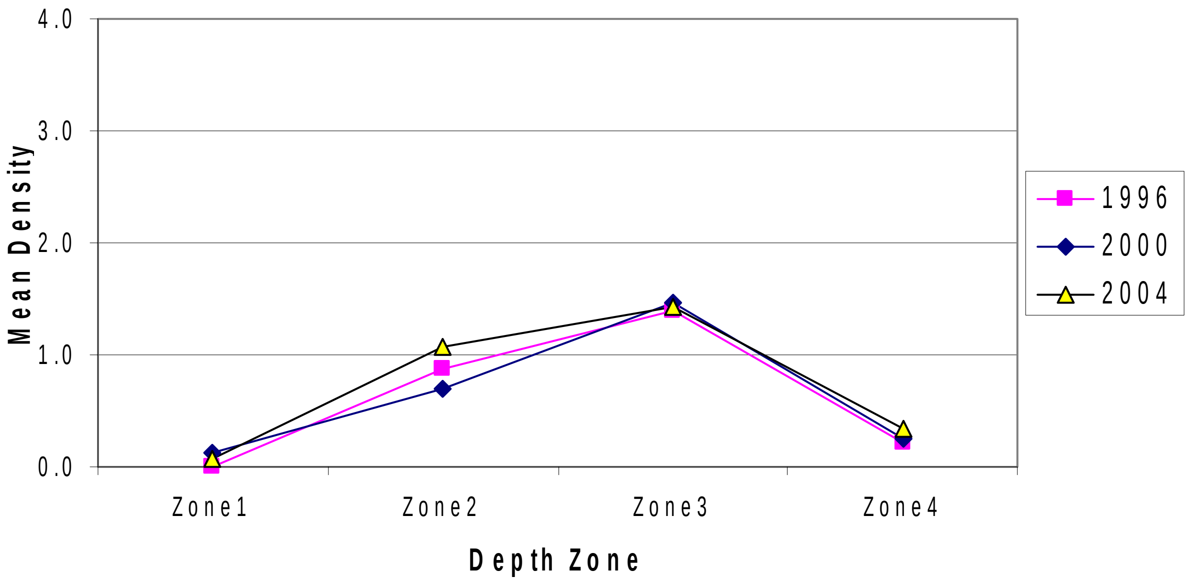

Figure 12. Mean density of *E. acicularis* in Axhandle Lake, by depth zone.

In 2000, different species dominated each depth zone. *Najs gracillima* still dominated the 1.5-5ft depth zone in 2000 and had a high mean density in 0-5 and 10-20ft depth zones (Figure 9, 10). However, *Potamogeton spirillus* was the species with the highest frequency in the 0-1.5ft depth zone in 2000 and occurred at its highest frequency and density in the 0-1.5ft depth zone, declining with increasing depth. *Eleocharis acicularis* dominated the 5-10ft depth zone in 2000 (Figure 11, 12). *Isoetes echinospora* was the species with the highest frequency in the 10-20 foot depth zone in 2000 (Appendices I-VI).

THE COMMUNITY

The Coefficients of Community Similarity is a measure of the percent similarity between two communities. Coefficients less than 0.75 indicate that the two communities are less than 75% similar and considered to be significantly different. The coefficients for Axhandle Lake indicate that the 1996 and 2000 aquatic plant communities were 78% similar and the 2000 and 20004 communities were 80% similar, suggesting no significant change between these years (Table 9).

The coefficient comparing the 1996 and 2004 communities measure any accumulating change over the 8 eight years between the first and third study. These communities are still just over 75% similar, therefore there has been no significantly change in the composition of the Axhandle Lake aquatic plant community from 1996 to 2004 (Table 9).

Table 9. Coefficients of Community Similarity

	Coefficient	Similarity
1996-2000	0.779	78%
2000-2004	0.802	80%
1996-2004	0.754	75%

Besides significant compositional changes, various parameters can measure other types of changes or small changes in the composition of the community.

Changes in the plant community from 1996 to 2004 (Table 10) are:

1) an increase in the number of species found at the transects
2) an increase in species richness (average number of species per site)
3) an increase in the percentage of the vegetated littoral zone
4) an increase in the coverage of all three types of plant structure (emergent, submergent and floating-leaf)
5) an increase in the Floristic Quality (discussed later), the community's closeness to an undisturbed condition
6) a small increase in the quality of the aquatic plant community (AMCI discussed later)
7) an increase in the Simpson's Diversity Index. Simpson's Diversity Index was 0.89 in 1996, 0.92 in 2000 and 0.91 in 2004, indicating very good to excellent diversity in the aquatic plant community. A rating of 1.0 would mean that each individual plant in the lake would be a different species (the most diversity achievable).

The largest percentage increase was in the percent of sample sites supporting emergent vegetation, a two-fold increase.

Table 10. Changes in the Axhandle Lake Aquatic Plant Community, 1996-2004

	1996	2000	2004	Change 1996-2004	%Change 1996-2004
Number of Species	27	31	30	3.0	11.1%
Maximum Rooting Depth (ft.)	30	30	30	0.0	0.0%
% of Littoral Zone Vegetated	92	95	96	3.8	4.1%
%Sites/Emergents	5.0	10.2	10.1	5.1	102.0%
%Sites/Submergents	87.4	91.5	94.1	6.7	7.7%
%Sites/Floating-leaf	22.7	23.7	33.6	10.9	48.0%
Simpson's Diversity Index	0.89	0.92	0.91	0.0	2.2%
Floristic Quality	38.80	39.18	41.41	2.6	6.7%
Average Coefficient of Conservatism	7.76	7.28	7.69	-0.1	-0.9%
AMCI	68	70	69	1.0	1.5%
Species Richness	2.45	2.91	3.34	0.9	36.3%

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols et. al. (2000) was applied to Axhandle Lake (Table 10). Values between 0 and 10 are given for each of seven measures of the quality of an aquatic plant community. The highest value for this index is 70. The AMCI for Axhandle Lake was 68 - 70 in 1996 - 2004. These values are nearly as high as possible and rank the aquatic plant community in Axhandle Lake as one of the highest quality aquatic plant communities in Wisconsin and the Northern Lakes and Forest Region.

Table 11. Aquatic Plant Community Index, Axhandle Lake, 1996-2004

Category	Values		
	1996	2000	2004
Maximum Rooting Depth	10	10	10
% Littoral Zone Vegetated	10	10	10
Simpson's Diversity	8	10	9
# of Species	10	10	10
% Submersed Species	10	10	10
% Sensitive Species	10	10	10
% Exotic Species	10	10	10
Totals	68	70	69

A method for evaluating the closeness of an aquatic plant community to an undisturbed condition, using Coefficients of Conservatism, outlined by Nichols (1998) was applied to Axhandle Lake.

The 1996, 2000 and 2004 Average Coefficient of Conservatism for Axhandle Lake was within the upper quartile for all Wisconsin lakes and above the mean for lakes in the North Lakes and Forest Region (Table 12). This suggests that the plant community in Axhandle Lake is less tolerant of disturbance than the average lake in the North Lakes and Forest Region and within the group of lakes in the entire state that is least tolerant to disturbance.

Table 12. Mean Coefficient of Conservatism and Floristic Quality of Axhandle Lake, Compared to Wisconsin Lakes and Region Lakes.

	Average Coefficient of Conservatism†	Floristic Quality‡
Wisconsin Lakes	5.5, 6.0, 6.9*****	16.9, 22.2, 27.5*****
NLF	6.1, 6.7, 7.7*****	21.9, 28.3, 36.6*****
Axhandle Lake, 1996-2004		
1996	7.76	38.80
2000	7.28	39.18
2004	7.69	41.41

† - Sample of Wisconsin 554 lakes ranged from a low of 2.0 (most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).

‡ - Sample of 554 Wisconsin lakes ranged from a low of 3.0to a high of 44.6

* - upper limit of lower quartile, mean, lower limit of upper quartile

The Floristic Quality Index for Axhandle Lake was in the upper quartile of Wisconsin Lakes and lakes in the Northern Lakes and Forest Region in 1996, 2000 and 2004 (Table 12). This suggests that the plant community in Axhandle Lake is within the group of lakes that are closest to an undisturbed condition.

Disturbances can be of many types:

1) Direct disturbances to the plant beds result from boat traffic, plant harvesting, chemical treatments, the placement of docks and other structures, etc.
2) Indirect disturbances can be the result of factors that impact water clarity and thus stress species that are more sensitive: resuspension of sediments, sedimentation from erosion, increased algae growth due to nutrient inputs.
3) Biological disturbances include the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores, destruction of plant beds by the fish population, etc.

The aquatic plant community changes when species within the community change (Appendix X).

Species that occurred at the transects in only one or two of the study years were species that occurred at only a few sites and could easily have been missed if the transects shifted slightly: *Calamagrostis canadensis, Chamaedaphne calyculata, Cladium mariscoides, Najas flexilis, Nuphar variegata, Potamogeton epihydrus, P. foliosus, P. gramineus, P. natans, Scirpus validus, Sparganium fluctuans, Triadenum fraserii, Utricularia gibba.*

The species that realized the greatest increase in frequency, mean density and dominance from 1996 to 2004 was *Potamogeton spirillus* (Appendix VII). Other species that increased at least two-fold were *Brasenia schreberi, Eriocaloun aquaticum* and *Myriophyllum tenellum.*

Besides the species that did not occur in 2004, the species that realized the greatest decline in frequency, density and dominance was *Foninalis* spp., aquatic moss and *Nitella* sp, a macrophytic algae. The macrophyte with the greatest decrease in frequency was *Juncus pelocarpus* (Appendix X).

VI. DISCUSSION

Based on nutrient, algae and water clarity data, Axhandle Lake appears to be gradually changing from an oligotrophic lake with very good water quality and clarity to a mesotrophic lake with good water quality and clarity. Nutrients and algae have increased during the years that Axhandle Lake has been monitored. Crossing this threshold may result in increased aquatic plant growth and more frequent algae blooms.

The watershed that drains into Axhandle Lake is relatively small and should not significantly impact water quality in the lake. Nutrient enrichment to Axhandle Lake has likely from shoreline properties and past inputs from the game farm on Dark Lake.

Although Axhandle Lake's soft water could limit aquatic plant growth, other factors favor plant growth:

1) the moderately sloped littoral zone
2) the good water clarity
3) the prevalence of silt sediments, favorable for plant growth
4) the mesotrophic status.

Current Aquatic Plant Community

Axhandle Lake has one of the highest quality aquatic plant communities in the state and region. According to the Floristic Quality Index and Average Coefficient of Conservatism, Axhandle Lake is among the group of lakes in Wisconsin and the North Lakes and Forest Region that possess a plant community closest to an undisturbed condition and has a high intolerance to disturbance. Simpson's Diversity Index indicates that the aquatic plant community in Axhandle Lake has excellent species diversity.

40 aquatic plant species have been recorded colonizing Axhandle Lake, up to a maximum rooting depth of 15.5 feet. *Najas gracillima* has been the dominant species in the plant community, dominating all depth zones. *Eleocharis acicularis* has been the sub-dominant species. The soft water conditions in Axhandle Lake are likely a major determinant of the plant species composition. *N. gracillima*, the dominant species, is limited to low alkalinity conditions. Other common species in Axhandle Lake are also limited to water with low alkalinity:
Juncus pelocarpus, Isoetes echinospora, Potamogeton spirillus, Sagittaria graminea.
Less common species in Axhandle Lake that are limited to low alkalinity conditions:
Calla palustris, Elatine minima, Myriophyllum farwellii, M. tenellum, Potamogeton epihydrus, Ranunculus reptans, Sparganium fluctuans, Utricularia gibba (Nichols 1999).

The 1.5-5 foot depth zone supports the most abundant aquatic plant growth; the highest total occurrence of aquatic plants, the highest total density of aquatic plants and the greatest Species Richness (most species per site).

The commonly occurring plant species were found throughout the lake, except

Nymphaea odorata which has been absent from the eastern shore of the main basin and *Brasenia schreberi* and *Sagittaria* sp. rosettes appeared to be absent from much of the west shore of the main lake in 2004. These areas are where much of the "traditional development" occurs and the plants may be victims of disturbance at developed shorelines.

1996-2004 Changes

Axhandle Lake has shifted from an oligotrophic lake to a mesotrophic lake, indicated by increased phosphorus (nutrients) and chlorophyll (algae) and decreased water clarity.

The 1996, 2000 and 2004 aquatic plant communities were not significantly different. Even though the aquatic plant communities were not significantly different, there were small changes:

1) *Najas gracillima* remained the dominant species, its frequency and mean density have increased.
2) The percentage of vegetated sites increased.
3) An increase in the coverage of all three types of plant structure (emergent, submergent and floating-leaf).
4) There was a two-fold increase in the percent of sites with emergent vegetation.
5) The Floristic Quality and Aquatic Macrophyte Community Indices increased.
6) The total number of species and the number of species per site increased.
7) The Simpson's Diversity Index increased.
8) The total occurrence and total density of plants have increased
9) The number of species that are commonly occurring in Axhandle Lake have increased

Some of the species in Axhandle Lake that have increased from 1996-2004 are known to have the habit of growing to over-abundant levels when there is an excess of nutrients: *Brasenia schreberi* (317% increased frequency, 550% increased density), *Eleocharis acicularis* (19% increase), *Nymphaea odorata* (50% increased frequency, 90% increased density), *Pontederia cordata* (33% increased frequency, 67% increased density), *Vallisneria americana* (50% increase) (Nichols and Vennie 1991). Promoting conditions that allow some species to become over-abundant will result in more user conflicts and decreased species diversity as they crowd out other species. Reduced diversity in the aquatic plant community results in decreased diversity in the fish and wildlife community.

Current Management

Natural shoreline (wooded, shrub growth and native herbaceous plant growth) was found at 90% of the transects and protects approximately three-quarters of the shoreline of Axhandle Lake. Natural vegetation slows run-off of water into the lake, reducing inputs of nutrients and pollutants.

Disturbed shoreline was found at more than one-half of the sites and covers nearly one-quarter of the shoreline. Cultivated lawn, hard structures and rip-rap were all commonly occurring at the sample sites. Cultivated lawn can contribute pesticides and fertilizers to the lake water. Cultivated lawn and hard structures both result in increased run-off. Rip-rap does not protect the shoreline and filter run-off as well as biological methods of stabilizing shorelines.

VI. CONCLUSIONS

Axhandle Lake is a mesotrophic lake with good water clarity and water quality.

Axhandle Lake has excellent species diversity and one of the highest quality plant communities in the state and region. The aquatic plant community in Axhandle Lake is characterized by a high intolerance to disturbance and an extreme closeness to an undisturbed condition. The plant community is an assemblage of soft water species. The dominant species, four of the common species and six of the less commonly occurring species are species of soft water lakes. The 1.5-5ft depth zone supports the most aquatic plant growth.

Najas gracillima was the dominant aquatic plant species, dominating all depth zones; *Eleocharis acicularis* was the sub-dominant species. With 92-95% of the sites vegetated, it would appear that Axhandle Lake has overabundant plant growth, however, the sub-dominant species, *E. acicularis*, and many other species in Axhandle Lake are low-growing, turf-forming species. These species help protect the lake bottom and do not reach the surface to cause lake-user conflicts: *Elatine minima, Eleocharis acicularis, Ericaulon aquaticum, Isoetes echinospora, Juncus pelocarpus, Myriophyllum tenellum, Ranunculus reptans, Sagittaria graminea.*

There was not a significant change in the aquatic plant community between 1996 and 2004, but there have been some small changes. Some positive changes are:

1) An increase in the percentage of sites with emergent vegetation
2) An increase in the quality of the aquatic plant community
3) An increase in the number of plant species, Species Richness and species diversity.
4) An increase in the coverage of all three types of plant structure (emergent, submergent and floating-leaf)

Some changes that have occurred may be of concern and should be monitored to ensure that these changes are not the beginning of a trend.

1) An increase in the nutrient levels and algae growth that has shifted Axhandle Lake from an oligotrophic lake to a mesotrophic lake.
2) Increases in the occurrence and density of species that can become overabundant with an increase in nutrients: *Brasenia schreberi, Eleocharis acicularis, Nymphaea odorata, Vallisneria americana.*
3) An increase in the frequency and density of the dominant species, which would result in less diversity.
4) An increase in the number of species that are commonly occurring in the lake
5) An increase in the percent of vegetated sites
6) An increase in the total occurrence and density of plant growth

A healthy aquatic plant community plays a vital role within the lake community. Plants provide improved water quality and valuable resources for fish and wildlife. Lakes with a healthy and diverse community of native aquatic plants are more resistant to invasions of non-native species and excessive growth of more tolerant species.

Healthy aquatic plant communities improve water quality in many ways:
Aquatic plants trap nutrients, debris, and pollutants entering a lake;
Aquatic plants absorb and break down some pollutants;
Aquatic plants reduce erosion by stabilizing banks and shorelines, stabilizing bottoms, and reducing wave action;
Aquatic plants remove nutrients that would otherwise be available for algae blooms (Engel 1985).

A balanced, healthy aquatic plant community provides important fishery and wildlife resources. Plants (including algae) start the food chain that supports many levels of aquatic life and, at the same time, produce oxygen needed by animal life. Plants are used as food and cover by a variety of wildlife and as food, cover, and spawning sites by fish (Engel 1985) (Table 13).

Compared to non-vegetated lake bottoms, aquatic plant beds supported larger, more diverse invertebrate populations (Engel 1985). These larger and more diverse invertebrate populations will in turn support larger and more diverse fish populations. Mixed stands of aquatic plants support 3-8 times as many invertebrates and fish as monocultural stands. Diversity creates more microhabitats for the preferences of more species (Engel 1990).

Aquatic plant beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990). The coverage of aquatic plants in Axhandle Lake (92-95%) appears to be overly dense, but many of the species are low-growing species that will not restrict fish movement.

Management Recommendations
It is important to protect the water quality and aquatic plant community in Axhandle Lake. The lake is an example of a high-quality aquatic plant community.

1) Protect the natural shoreline around the lake that in turn protects the water quality and provides important habitat. Nearly one-quarter of the shoreline is disturbed with some type of development. This results in increased run-off to the lake, less filtering capacity for water run-off to the lake, less available habitat and increased nutrient input to the lake.
2) Restore natural buffers and emergent beds on shorelines that lack natural cover. This will better protect the shoreline, protect the water quality and provide wildlife and fish habitat. Nearly one-quarter of the shoreline has lost its natural cover.
3) Continue participation in the volunteer water quality monitoring program to determine if there is a real trend toward lower water quality.
4) Limit aquatic plant removal in Axhandle Lake, especially species valuable for habitat, such as the emergent plants and lily beds. Some species are already absent from the developed shorelines.

5) Designate Sensitive Areas in Axhandle Lake to protect the quality plant beds and preserve habitat.
6) Reduce nutrient input to Axhandle Lake. It appears that Axhandle Lake is in the early stages of being impacted by increased nutrients. There has been an overall increase in aquatic plant growth and the species that have increased most are those that are known to become overabundant in conditions of increased nutrients. The watershed of the lake is small, therefore, most nutrient inputs would likely come from the lakeshore properties.
    a. Maintain private septic systems to prevent nutrient enrichment of the lake.
    b. Eliminate the use of lawn chemicals and fertilizers that feed algae growth.
    c. Preserve and restore natural shorelines